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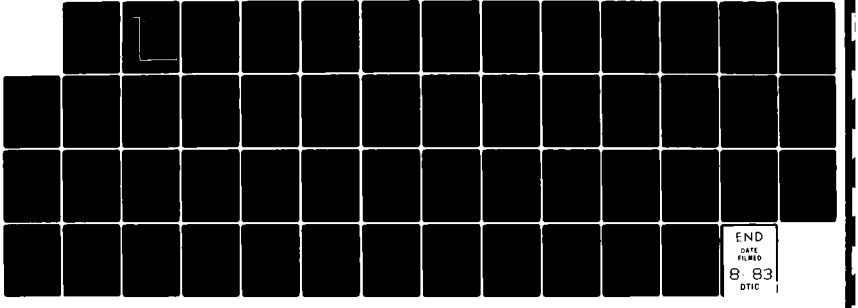

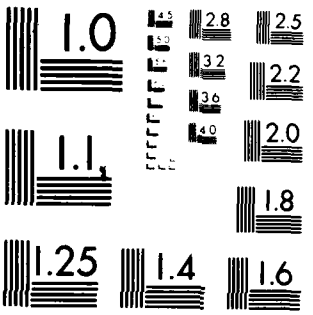

AFHRL-TP-82-25(I)

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AIR FORCE HUMAN RESOURCES LABORATORY

INTEGRATED CUING REQUIREMENTS (ICR) STUDY: FEASIBILITY ANALYSIS AND DEMONSTRATION STUDY

By

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OPERATIONS TRAINING DIVISION
Williams Air Force Base, Arizona 85224

June 1983

Final Technical Paper

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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This paper has been reviewed and is approved for publication.

THOMAS M. LONGRIDGE
Contract Monitor

MILTON E. WOOD, Technical Director
Operations Training Division

CARL D. ELIASON, Colonel, USAF
Chief, Operations Training Division

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
AFHRL-TP-82-25(I)

2. GOVT ACCESSION NO.
AD-A131039

3. RECIPIENT'S CATALOG NUMBER

4. TITLE *(and Subtitle)*
INTEGRATED CUING REQUIREMENTS (ICR) STUDY: FEASIBILITY ANALYSIS AND DEMONSTRATION STUDY

5. TYPE OF REPORT & PERIOD COVERED
Final

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Richard Farrell
Richard Barker

8. CONTRACT OR GRANT NUMBER(s)
F33615-79-C-0014

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Boeing Aerospace Company
P.O. Box 3999 M/S 87-77
Seattle, Washington 98124

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
62205F
61142302

11. CONTROLLING OFFICE NAME AND ADDRESS
HQ Air Force Human Resources Laboratory (AFSC)
Brooks Air Force Base, Texas 78235

12. REPORT DATE
June 1983

13. NUMBER OF PAGES
54

14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*
Operations Training Division
Air Force Human Resources Laboratory
Williams Air Force Base, Arizona 85224

15. SECURITY CLASS *(of this report)*
Unclassified

15.a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of this abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

air crew training device design
flying training
human engineering
human engineering guidelines
human factors
perceptual data base
sensation and perception
sensory data base
simulator design
users guide

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The goal of the Integrated Cuing Requirements (ICR) Study was to consolidate and synthesize existing human sensory/perceptual data, principles and models in a manner which would make this information readily accessible and useful to the community of aircrew training device (ATD) design engineers.

There exists an extensive body of research literature on human perception which could potentially be of value in the specification, design, and evaluation of aircrew training devices. The data in this domain are distributed among numerous different publications and are written in the specialized terminology of perceptual psychology.

DD Form 1473 EDITION OF 1 NOV 65 IS OBSOLETE
1 Jan 73

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Date Entered)*

Item 20 (*Continued*)

Consequently, this information is not generally accessible to ATD engineers. The goal of the ICR study was to extract and consolidate the relevant data into an accessible format and to provide, where feasible, a synthesis of the literature which included recommendations relevant to equipment design. The intended output of this activity was (a) an ICR Data Base containing the available sensory/perceptual data in a form useful for specification and design purposes, and (b) an ICR Users Guide to facilitate access to the data by the ATD engineer.

Volume I of this technical paper presents the results of an Independent Feasibility Analysis and a subsequent Demonstration Study Evaluation, the purpose of which was to develop, test, and refine an approach to the ICR Study objectives discussed above. These activities constituted Phase I of the effort. The project was structured such that no decision on full-scale implementation of the approach (Phase II) would be made until an evaluation of Phase I had been completed. Volume II of this technical paper contains the Phase I Demonstration Data Base and Users Guide.

AFHRL Technical Paper 82-25(I) June 1983

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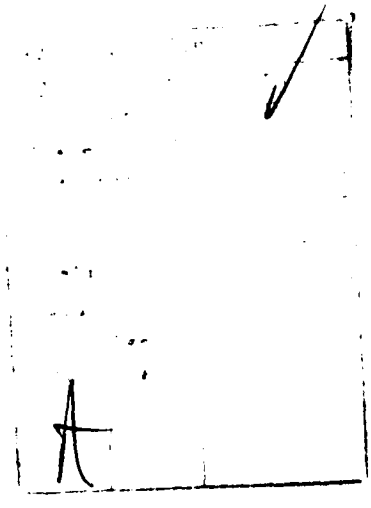


This publication is primarily a working paper.
It is published solely to document work performed.

PREFACE

This research supports the Air Combat Tactics and Training Thrust of the Air Force Human Resources Laboratory. By describing an approach to provide the sensory and perceptual data needed in the aircrew training device (ATD) design process, the research directly supports the Engagement Simulation Technology Subthrust of the AFHRL, Operations Training Division. The work was accomplished under contract by the Boeing Aerospace Company. This paper consists of material that was written and submitted by the contractor, but has been reorganized and edited by the Government.

This research program was conceptualized, initiated, and managed by Dr. Ken Boff, under the former Advanced Systems Division of the Air Force Human Resources Laboratory. The program at Boeing Aerospace Company was managed by Mr. Wolfe Hebenstreit. The principal research activity was accomplished by Mr. Richard Farrell and Dr. Richard Barker.

Although the research program described herein was terminated, a reorganized approach to achieve the original project goals was initiated by the Aerospace Medical Research Laboratory, with the support of the Air Force Human Resources Laboratory. That program, entitled Integrated Perceptual Information for Designers (IPID), is managed by Dr. Ken Boff.

TABLE OF CONTENTS

1.0 INTRODUCTION

The goal of the Integrated Cuing Requirements (ICR) Study was to consolidate and synthesize existing human sensory/perceptual data, principles and models in a manner which would make this information readily accessible and useful to the community of aircrew training device (ATD) design engineers.

There exists an extensive body of research literature on human perception which could potentially be of value in the specification, design, and evaluation of aircrew training devices. The data in this domain are distributed among numerous different publications and are written in the specialized terminology of perceptual psychology. Consequently, this information is not generally accessible to ATD engineers. The goal of the ICR Study was to extract and consolidate the relevant data into an accessible format and to provide, where feasible, a synthesis of the literature which included recommendations relevant to equipment design. The intended output of this activity was (a) an ICR Data Base containing the available sensory/perceptual data in a form useful for specification and design purposes and (b) an ICR Users Guide to facilitate access to the data by the ATD engineer.

Volume I of this technical paper presents the results of an Independent Feasibility Analysis (Section 2.0) and a subsequent Demonstration Study (Section 3.0), the purpose of which was to develop, test, and refine an approach to the ICR Study objectives discussed above. Appendices A and B, respectively, present the Literature Search and Review Plan and the Data Base and Users Guide Development Plan for the achievement of these objectives. These activities constituted Phase I of the effort. The project was structured such that no decision on full-scale implementation of the approach (Phase II) would be made until an evaluation of Phase I had been completed. Volume II of this technical paper contains the Phase I Demonstration Data Base and Users Guide. Figure 1 diagrams the planned sequence for Phases I and II of the program.

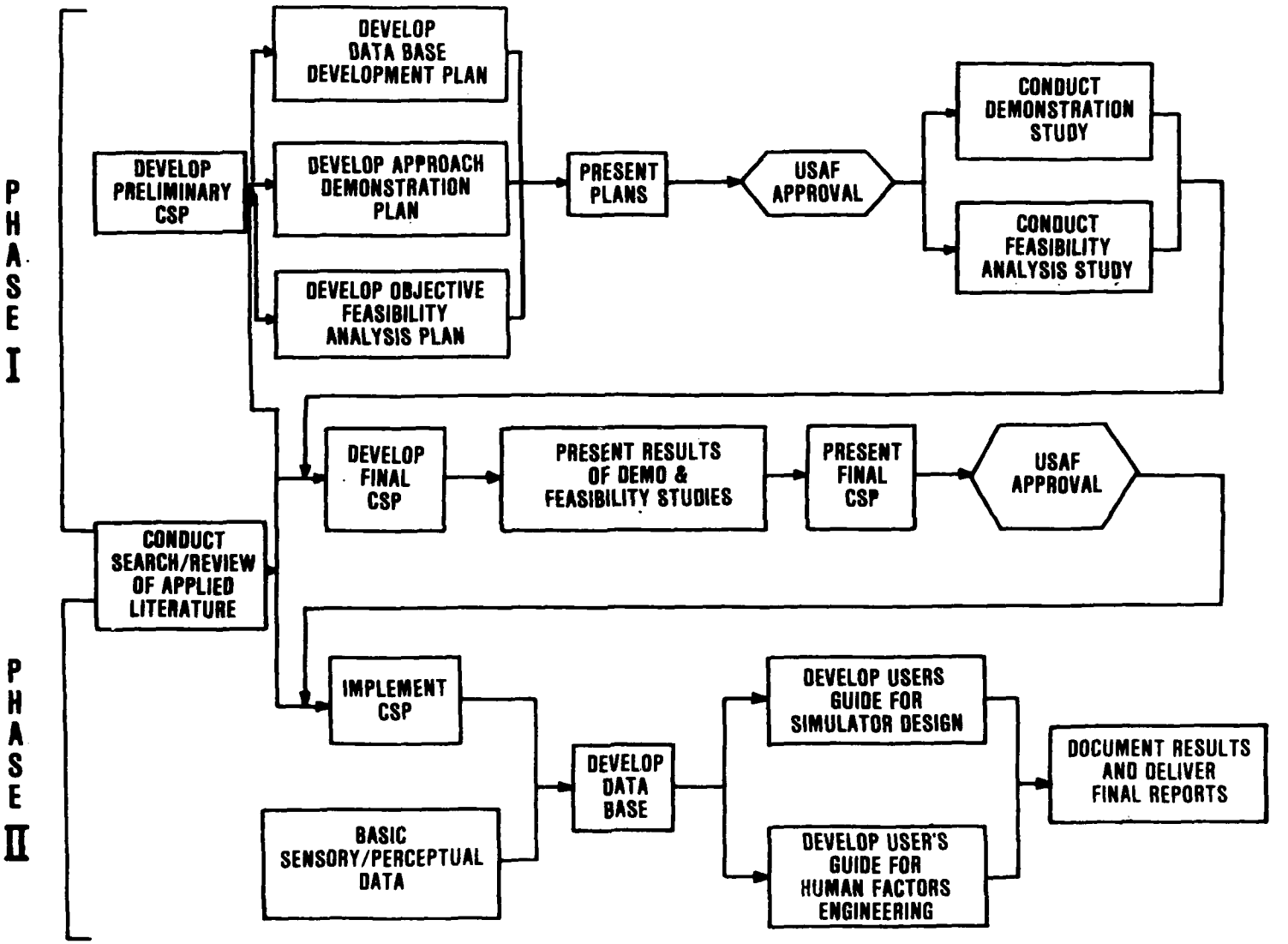


FIGURE 1 ICR PROGRAM FLOW

2.0 INDEPENDENT FEASIBILITY ANALYSIS

2.1 Objectives

This analysis was intended to improve the study approach by soliciting critiques, recommendations, and fresh insights from recognized experts in the areas of perception, training psychology and simulation engineering. The analysis was to provide an objective assessment of the feasibility of the basic study assumptions and the overall approach as well as assessing the likelihood of successfully achieving the study objectives.

2.2 Approach

Three experts representing the appropriate areas of expertise initially conducted independent, structured reviews of the study plan. This was followed by a team review at the contractor's facility to produce recommended changes and feasibility assessments. An overview of the assessment is presented in Figure 2.

2.3 Detailed Plan

2.3.1 Selection and Approval of Experts

Three experts were selected and approved by the Air Force Contract Monitor (AFCM) for accomplishing this analysis. Personnel selected and their areas of expertise were as follows:

Dr Hershel W. Leibowitz: Evan Pugh Professor of Psychology Pennsylvania State University	Perception
Dr Robert L. Howe: Department of Aerospace Engineering University of Michigan	Computer Systems

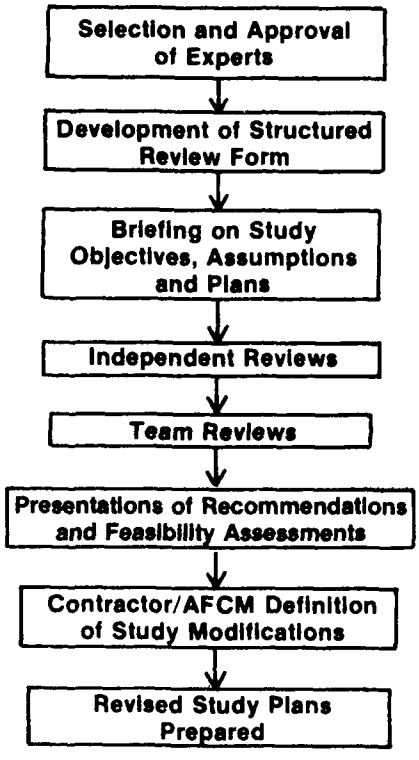


Figure 2 Independent Feasibility Assessment Plan

Dr Robert R. Mackie: Training
President, Human Factors Research, Inc.

2.3.2 Development of Structured Review Form

A structured review form was developed to enhance objectivity and control the scope of the reviews. The experts were encouraged to add additional comments, criticisms, and recommendations. The review form was intended to serve as a checklist of critical areas in the planned approach and suggest criteria for the assessment of effectiveness and feasibility. An outline of the form is presented in Table 1. It was designed to help assure that the details of the intended approaches to the individual program elements, as well as the overall goals of the program, were properly assessed.

2.3.3 Briefing

A briefing of the review team was held at the contractor's facility to establish a solid base for the subsequent reviews. Copies of the Statement of Work, relevant plans, and the structured review form were sent to the reviewers prior to the briefing to provide an initial orientation. This briefing provided in-depth descriptions of the study objectives and assumptions as well as the study approach as defined by the literature search plan and the preliminary comprehensive study plan. The briefing included a discussion of the feasibility analysis objectives, its importance in the overall study approach, and detailed instructions for conduct of the reviews.

TABLE 1

REVIEWER'S CHECKLIST

A. Study Assumptions

B. Literature Search Plan
   1) Search Terms
   2) Literature Sources
   3) Screening Criteria
   4) Prioritization
   5) Evaluation Criteria
   6) Summary Formats

C. Data Base Development Plan
   1) Preliminary Topic List
   2) Approach to Identification of Topics
      a. ATD Design Parameter Categories
      b. Training Cue Categories
      c. Perceptual Categories
   3) Data Integration Process
      a. Combined Pilots
      b. Principles and Models
   4) Methods of Presentation
      a. Entry Techniques
      b. Recommendations
      c. Tutorial Material, Analyses, etc.
      d. Extracted and Formatted Data
   5) Organization of Users Guide/Data Base

D. Demonstration Study
   1) Specific Problem Areas
      a. Data Availability
      b. Impact on ATD Design
   2) Simulated Design Exercises
   3) Impact on ATD Specification and Evaluation

E. Overall Assessment
   1) Feasibility
   2) Problem Areas
   3) Potential for Approach Improvement

2.3.4 Independent Reviews

The initial reviews were conducted independently by each expert at his own facility. A period of approximately two weeks was used for this process. Each of the experts prepared materials for the team review.

2.3.5 Team Review

After the individual reviews had been completed, the review team met at the contractor's facility to compare and collate responses to the structured review form, general comments, and recommendations. These results were reviewed by contractor personnel with the review team to establish the desirability and feasibility of incorporating the recommended changes into the study approach.

2.3.6 Presentation of Results

The results of the team review were jointly presented to the AFCM by the contractor and independent experts at a meeting held at the contractor's facility. This presentation included the following program.

- o Probability of success for the planned program.
- o Recommended changes.
- o Probability of success with recommended changes.

2.3.7 Definition of Study Modifications

After review of the recommended changes, contractor personnel and the AFCM selected specific changes based on feasibility and likelihood of payoff. These changes were incorporated in the Demonstration Study.

2.4 Structured Review Form

Appendix C contains the complete text of the review form for the Independent Feasibility Analysis. A summary of the results of the analysis is contained in Section 2.5.

2.5 Results

The consensus of the team was that the ICR Study, as conceived, is a major undertaking that would make a much needed contribution to the design of aircrew training devices and that this contribution would have a positive cost/benefits impact. Within this general finding, the team had the following specific comments and questions:

It was pointed out that the ICR project objectives involve identifying both the data needed to support ATD design and the data available in the literature to meet these requirements. Through the comparison of these two sets of data, gaps in the available data should be identified in a systematic fashion, and these gaps must be prioritized in terms of their need for inclusion in future research programs.

The availability of a broad base of established cue requirements upon which to draw during the development of the Data Base and Users Guide was questioned. Such information, if available, would be of significant use to the ICR program. Its unavailability would result in some lack of specificity that might detract from the utility of the product. There was general agreement that cue requirements information specific to air-to-air, air-to-surface, and nap-of-the-earth flying was far from complete.

Concern was expressed over the ability of the contractor to select, review, and summarize the pertinent literature without introduction of unintentional bias due to the limited number of reviewers employed. In response, it was noted that the contractor's in-house team had been expanded by the addition of two subcontractors: one in the area of audition and the other in vestibular perception of force and motion.

The issue was raised of the relationship of the ICR study to the overall simulator procurement process. While the influence of improvements in

hardware capability on simulator design was not the topic of the ICR study, it was deemed essential to keep this capability in mind when establishing ICR data requirements and when developing the data base materials. It was anticipated that the Air Force technical support team could contribute significantly in this area.

Concern was expressed that a Demonstration Study topic be chosen which would be sufficiently specific to permit development of an adequate sample Data Base and Users Guide on which basis the Phase I program would be evaluated.

3.0 DEMONSTRATION STUDY

3.1 Introduction

The requirements imposed on an ATD vary as a function of the flight task to be trained. An ATD suitable for the landing task is not necessarily adequate for air-to-air combat. Although training mission analysis was not within the scope of the ICR Study, it did place emphasis on data relevant to the design of ATDs for training the most combat-critical portions of flight. Hence, data relevant to nap-of-the-earth flight or air-to-air combat would receive more attention in the ICR Study than data relevant to takeoff and landing.

The ICR documentation is divided into two parts: the Data Base and the Users Guide.

The Data Base contains the extracted research data, organized for easy access and summarized in terms of recommendations or implications for ATD design. The format facilitates expansion beyond the currently planned sections if additional topic areas are identified as useful.

The Users Guide provides a means of accessing and utilizing the Data Base. Because access is so important in a document intended for engineering use, different Data Base entry methods are provided to meet the needs of individual users. These include tables of contents, an index and several types of design-oriented analyses. (In addition to the entry methods in the Users Guide, access to related topics is provided within the Data Base by cross references to other Data Base sections.)

Preparation of the Data Base and Users Guide followed an Air Force-approved Preliminary Comprehensive Study Plan developed early in the program. The major steps called for in these plans are summarized in Section 3.3 below.

As with the Data Base, these plans were developed in a preliminary form and reviewed by independent outside consultants, whose comments and suggestions were used to improve the product.

The primary methods of access in the sample User's Guide were a summary table of contents, a detailed table of contents listing every subsection in the Data Base, and an index. A brief description was also included of other methods of access planned for inclusion during the proposed Phase II portion of ICR. These would provide access in terms of specific hardware features or in terms of the training mission of an ATD (for example, low-level flight or air-to-air combat).

3.2 Sample Data Base and Users Guide

The preparation of the sample Data Base followed a series of steps designed to ensure that the data were maximally useful to the ATD engineer and were scientifically valid. These steps included:

1) Identification of the data topics pertinent to ATD specification, design, or evaluation. This step utilized the experience of ATD engineers and of scientists involved in human perception who had participated in ATD specification or evaluation.

2) Selection, from the list developed in Step 1, of two sample data topics for incorporation into the sample Data Base. These were (a) judgment of surface orientation and shape, and (b) visual induction of self-motion.

3) Collection and review of research literature on these sample topics.

4) Extraction from this literature of the research data relevant to ATD design.

5) Formatting of these data for easy interpretation by ATD engineers.

6) Summarization of these data into preliminary recommendations applicable to ATD specification, design or evaluation.

7) Review of the preliminary recommendations by outside expert consultants.

8) Incorporation of the consultants' comments, changes and suggestions into the material.

9) Preparation and delivery of the sample Data Base material for evaluation by a representative group of ATD engineers.

A sample Users Guide was prepared to provide access to specific topics in the sample Data Base.

3.3 Evaluation Procedure

An independent group of ATD design engineers was selected by the Air Force to serve as reviewers of the Phase I product. These reviewers were asked to respond to a total of eight specific questions covering three general evaluation topics. These topics were (a) the accessibility of the data in the Data Base, (b) the formatting and presentation of the data, and (c) the usefulness of the data. General comments were also requested.

To assist the reviewers in making their evaluation, each was provided with a series of hypothetical design problems. By attempting to solve these design problems, the reviewer obtained a better understanding of what data the Data Base contained and how adequately data on a specific topic could be located and interpreted.

The text of the user's evaluation form appears in Appendix D.

3.4 Results

For each of the evaluation questions, most of the reviewers provided a general response, such as "good" or "poor", and a number of specific responses in the form of comments about particularly good or poor features. Responses to six of the eight questions are summarized in Figures 3 through 8. (Not all reviewers responded to all questions, so the number of reviewers represented in these figures varies from 9 to 18.) Questions to which fewer than nine reviewers responded are not included on this summary.

Each figure contains (a) the specific question from the evaluation form to which the results apply, (b) a histogram of reviewer "good"/"poor" responses to the question, (c) a statement of the percentage of these responses that were favorable, and (d) an anecdotal sampling of the specific comments that the question elicited.

The histograms in these figures serve to illustrate that the responses were generally favorable. The reviewers rated the Demonstration Study sample ICR material as well presented, easily accessible, and potentially useful.

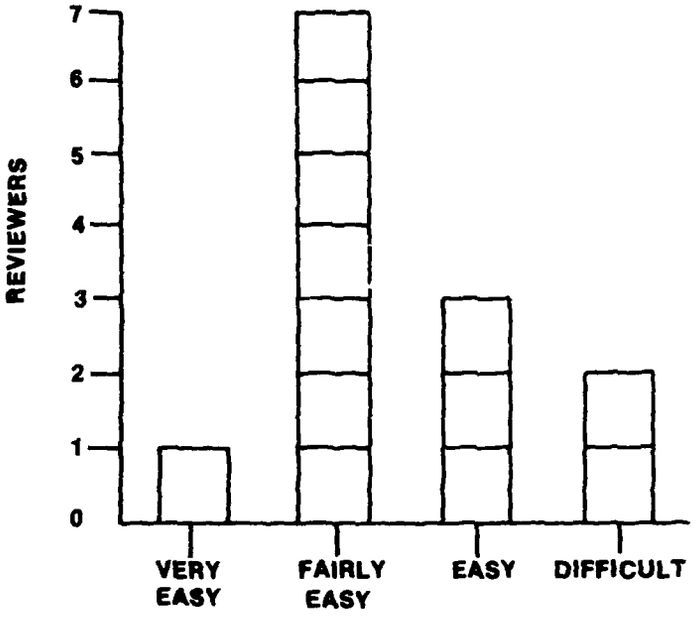
Specific comments included both positive and negative evaluations of particular aspects of the sample material and suggestions for refinements. All of these comments contributed to the identification of features which should be retained or improved. For example, the results indicated in-depth design examples should be added to make it apparent to engineering-oriented users how to apply the data to specific simulator design problems.

FIGURE 3

ACCESS-I

A1 HOW EASY WAS IT TO LOCATE MATERIAL RELEVANT TO A PARTICULAR TOPIC?

62% RATED THE DATA AS EITHER VERY EASY OR EASY TO ACCESS.



REVIEWER COMMENTS

"I FOUND IT FAIRLY EASY TO LOCATE MATERIAL RELEVANT TO A PARTICULAR TOPIC".

"IN GENERAL, THE ACCESS CAPABILITY IS VERY GOOD."

"THE AUTHORS SEEM TO BE ALL HUNG UP ON THE METHODOLOGY OF HOW TO FIND SOMETHING."

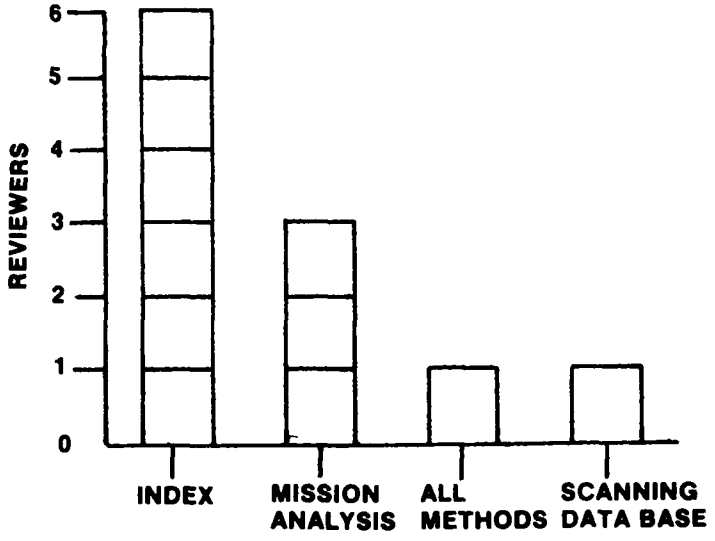
"PERSONALLY, I FOUND THE SUBJECT TITLING BREAKDOWN CONFUSING."

FIGURE 4

ACCESS-II

A3 WHICH METHOD(S) OF ACCESS ARE MOST EFFECTIVE?

55% RATED THE INDEX AS THE MOST EFFECTIVE.



REVIEWER COMMENTS

"THE INDEX APPEARS TO BE THE MOST EFFECTIVE BECAUSE IT ALLOWS QUICKER ACCESS."

". . .A SINGLE METHOD OF ENTRY IS ALL THAT IS REQUIRED...A GOOD INDEX...WOULD BE GREAT..."

". . .SECTION 8.0...SEEMS LIKELY TO GET VERY LARGE AND CUMBERSOME..."

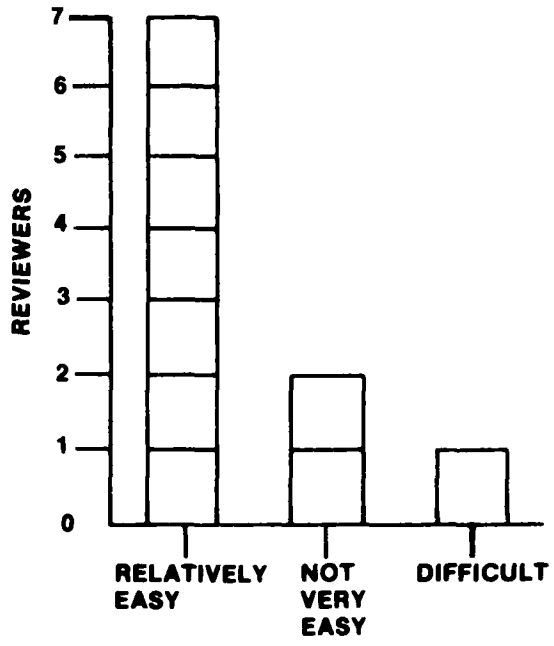
SEVERAL REVIEWERS EITHER COULD NOT FIND THE KEY WORD THEY WERE LOOKING FOR IN THE INDEX, OR THE KEY WORD THEY FOUND DID NOT LEAD THEM TO THE INFORMATION THEY WANTED. THEIR KEY WORDS ARE BEING EVALUATED.

FIGURE 5

PRESENTATION-I

B1 HOW EASY WAS THE PRESENTATION FORMAT TO FOLLOW?

70% RATED THE PRESENTATION FORMAT AS EASY TO FOLLOW.



REVIEW COMMENTS

"GENERALLY EASY TO FOLLOW..."

"DATA BASE WAS RELATIVELY EASY; HOWEVER, THE USER'S GUIDE SEEMED OVERLY REDUNDANT."

"A REFERENCE TO A PARTICULAR PAGE LAUNCHES THE READER INTO THE MIDDLE OF A DISCUSSION."

"THE UNDERLINED RECOMMENDATIONS WERE DISTRACTING."

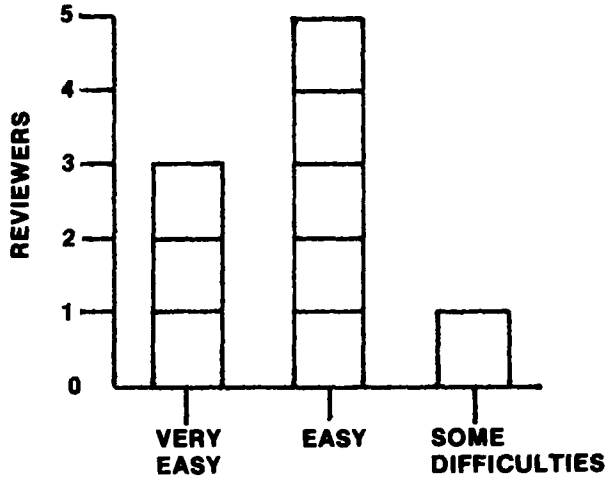
"I WOULD PREFER THE "RECOMMENDATION" COLUMN ON THE RIGHT AND THE "SUPPORTING DATA" COLUMN ON THE LEFT..."

FIGURE 6

PRESENTATION II

B2 HOW EASY WAS IT TO INTERPRET THE DATA AND RECOMMENDATIONS PRESENTED?

89% RATED THE DATA AND RECOMMENDATIONS AS EASY TO INTERPRET.



REVIEWER COMMENTS

"ALL RECOMMENDATIONS ARE CLEAR AND EASILY UNDERSTOOD..."

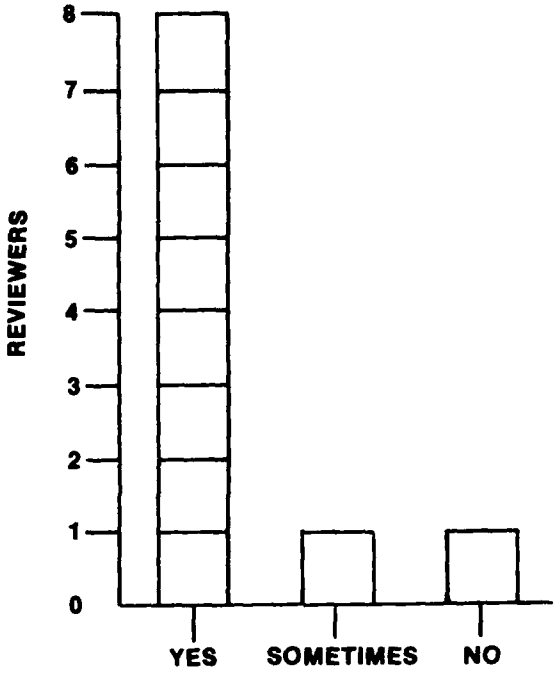
"THE RECOMMENDATIONS WERE VERY CLEAR."

"IN MOST INSTANCES, NOT QUITE ENOUGH INFORMATION IS GIVEN TO ALLOW ME TO JUDGE THE VALIDITY...(I.E., NO. OF Ss...)

"IN NOT ALL CASES ARE RECOMMENDATIONS WRITTEN AS RECOMMENDATIONS; OFTEN THEY SOUND MORE LIKE CAUTIONS."

FIGURE 7

PRESENTATION-III



B4 DID THE PRESENTATION ALLOW YOU TO SEE THE EXTENT TO WHICH A RECOMMENDATION WAS SUPPORTED BY RESEARCH DATA?

80% RATED THE PRESENTATION FORMAT AS SHOWING THE SUPPORT FOR RECOMMENDATIONS.

REVIEWER COMMENTS

"YES, I LIKED THE FORMAT HERE."

"YES, --GOOD JOB."

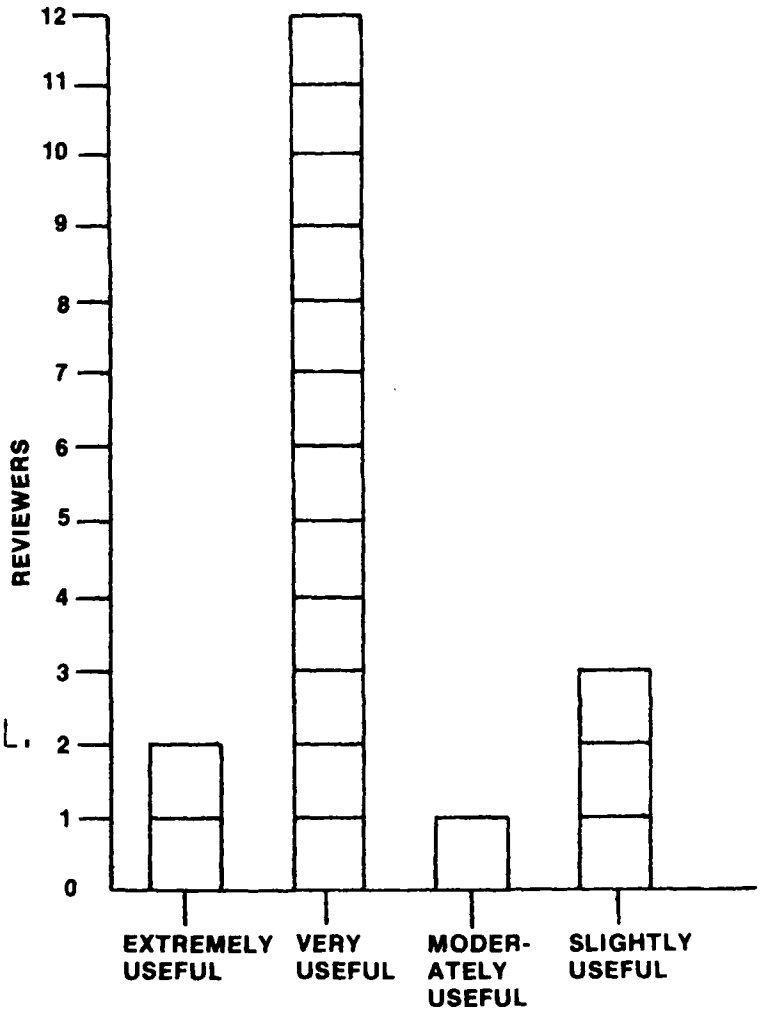
"YES, PROVIDED BIBLIOGRAPHIES WERE CITED."

"ONLY IN THE CASE WHERE DATA WAS SPARE AND WEAK. WHEN MANY STUDIES SUPPORTED A RECOMMENDATION, LITTLE DETAILED DATA SEEMED TO BE PRESENTED AS SUPPORT."

"NO, NO, NO. THIS IS ONE OF THE WORST FEATURES."

FIGURE 8

USEFULNESS



C1 HOW USEFUL A RESOURCE WILL THE ICR DOCUMENTATION BE IN ITS FINAL FORM?

78% RATED ICR AS EITHER EXTREMELY USEFUL OR VERY USEFUL.

REVIEWER COMMENTS

"...EXCELLENT...HOWEVER, THE ICR DEMONSTRATION IS SO INCOMPLETE AND LIMITED...THAT THE ACCESS SYSTEMS CANNOT BE EVALUATED PROPERLY."

"WITH A COMPREHENSIVE ACCESS SYSTEM THAT DOESN'T TAKE AN HOUR TO WADE THROUGH, SOMEONE MIGHT USE IT."

4.0 CONCLUSIONS

The results, though based on a limited sample of data, were consistent with the general conclusion that the objectives and associated products of the ICR study are:

a. Feasible

b. Useful to ATD design engineers.

However, an assessment by the Air Force management team also led to the unequivocal conclusion that a significant restructuring of the planned approach would be required in order to provide the depth of data coverage and synthesis needed to achieve the study objectives. In particular, it was concluded that it was unlikely that any one contractor could provide the required depth of coverage and associated expertise within the Government's cost constraints. The existing contractual effort was therefore terminated. A restructured approach to provide direct access to the required expertise was designed and implemented by the Air Force Aerospace Medical Research Laboratory in cooperation with the Air Force Human Resources Laboratory.

APPENDIX A

LITERATURE SEARCH AND REVIEW PLAN

1.0 Figure A-1 diagrams the literature search and review plan. The literature search and review will begin with a statement of the required data described in the Data Base Development Plan. These requirements will be prioritized and used to direct a search of the literature. When promising literature is obtained, it will be screened, summarized, and evaluated for inclusion in the ICR data base. Access to and control of the literature obtained will be achieved by means of a computerized bibliography. Data covering sensory/perceptual topic areas specified in the preliminary and final comprehensive study plans will be extracted from the literature that meets the evaluation criteria and will be formatted and integrated into the ICR data base.

2.0 Evaluation of potentially useful literature will occur at several points during the search and review. To reduce the chance of missing useful literature, the threshold for obtaining a copy of a potentially useful article will be kept very low. The resulting literature must then pass several increasingly critical evaluations before reaching the point where a significant amount of contractor time is spent in extracting and formatting data.

3.0 To ensure the literature search and review is directed toward the most important data topics and the most relevant data sources, priorities will be established throughout the program. The data base content requirements will be prioritized to establish which topics will receive the largest initial emphasis. During the literature screening process, articles will be prioritized for summarization and evaluation on the basis of their probable contribution to the data base.

4.0 Rapid feedback from the results of the literature search and review will be essential to ensure particular topic areas are not being overworked or underworked. This feedback will be obtained by continual review of the outputs from the literature search and review as articles are summarized and evaluated for content and as data are extracted and formatted for incorporation into the ICR data base. By comparing these outputs with the

data base content requirements, it will be possible to determine what changes in emphasis are needed in the process of searching for and identifying additional literature. This evaluation of the output from the literature search and review will also help in establishing the final data base content requirements.

5.0 Most topic areas will be the subject of several publications. Knowledge of these similar articles is important during the evaluation process because they indicate the uniqueness and hence the importance of a particular study on the topic area, and they provide comparative results. It is also essential to have these groupings of articles identified prior to formatting the data from an article because it will generally be necessary to place the data in a consistent format, or even to place data from several studies on a single figure. Many of the several articles on a single topic area will be identified through the reference lists in the more recent articles, some will be identified through subject indexing within the bibliography, and others will be identified by program personnel as they search for literature on a particular topic.

6.0 The specific sensory/perceptual areas in which data will be extracted, formatted, and integrated into the ICR data base will be controlled by the Data Base Development Plan.

7.0 The bibliography, literature summaries, and extracted and formatted data will be reported in the form of a Technical Literature Review. As this material is integrated into the ICR data base, the resulting data base will be submitted to the Air Force.

8.0 Literature Evaluation

8.1 Each article that appears promising for incorporation in the ICR data base will be formally evaluated. The purpose of this evaluation is to establish how safe it is to make use of the results and conclusions reported in the article in the ICR data base. Forms will be used to provide a record of each evaluation and to ensure the evaluator can quickly and efficiently consider all the evaluation topics. To reduce the time lost on irrelevant topics, the evaluator will have the option of not entering a formal rating for

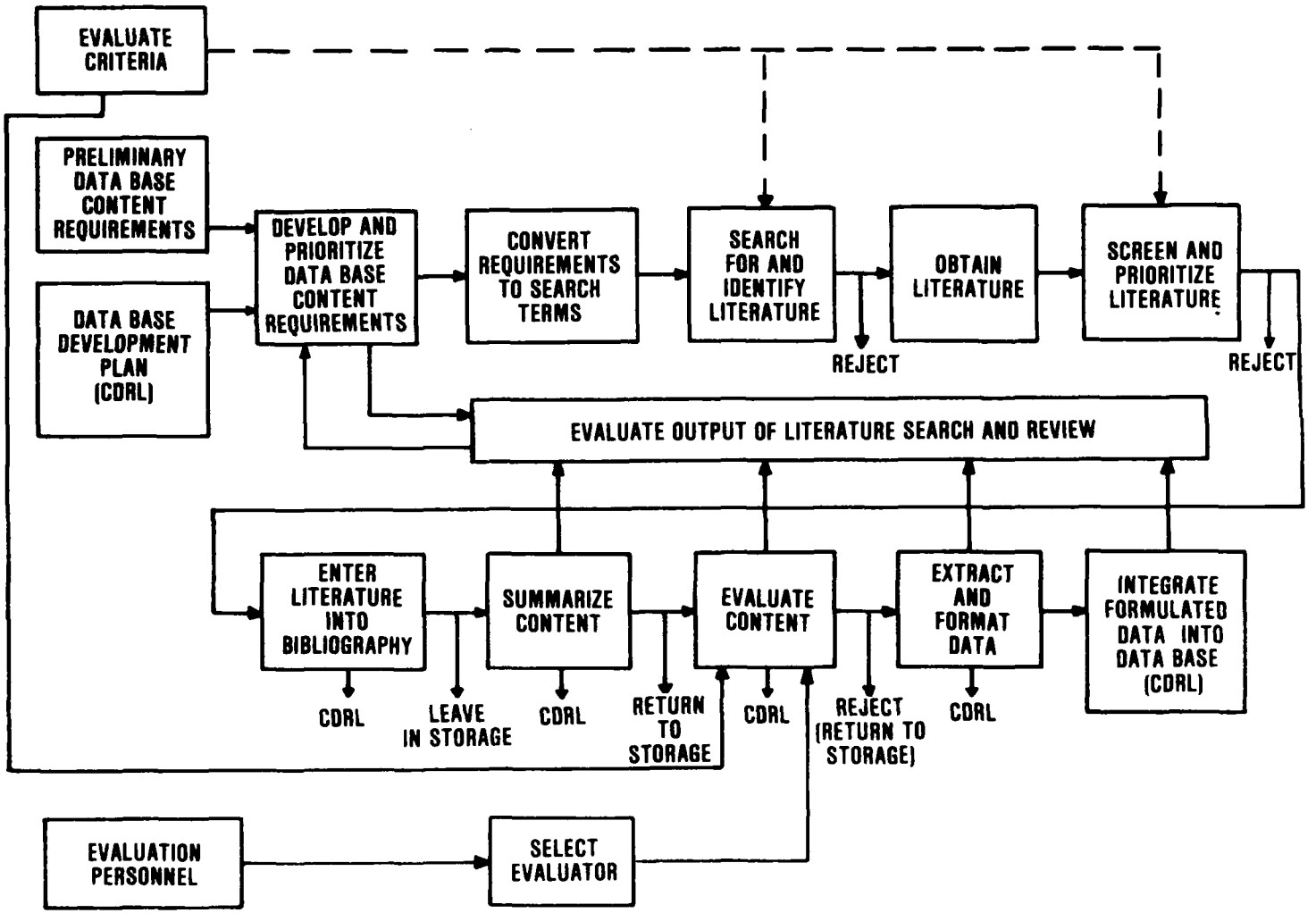


Figure A-1 Literature Search and Review Flow

evaluation topics that have little relevance to the usefulness of a particular article.

8.2 Evaluation criteria will vary with the type of article involved. For a report of an experiment, the evaluation will consider the reliability and validity of the experiment and the experimental results, and the correctness and degree of certainty in the conclusions drawn from these results. For an analytical article, the concern will be with the validity of the author's initial assumptions, analysis, and conclusions. Tutorial and review articles will be treated like analytical articles except that the concern will be with the completeness and representativeness of the literature covered rather than with the starting assumptions.

8.3 Evaluators for a particular article will be selected on the basis of their expertise in the technical area covered by the article. The number of evaluators will depend on the importance of the information contained and on the potential controversy involved in applying this information to simulator design. In most cases, a single evaluator in addition to the individual who summarized the article will be sufficient.

9.0 Data Extraction and Formatting

9.1 For data evaluated as useful contributions to the ICR data base, the relevant information contained in each article will be extracted. The summary of the article will serve as a starting point, but more details will be necessary, particularly in the area of experimental conditions and results.

9.2 The specific information to be formatted for each article or group of articles will be that required to integrate this material into the ICR data base. This will include the experimental results obtained, usually in a quantitative, easily assimilated graphic form, plus whatever background details are necessary to interpret and use these data. This will generally be the same type of information summarized earlier, with enough detail for the data user to understand how the data were obtained and how much reliance can be placed in the data.

9.3 This information will be formatted for each access and interpretation. In some cases, it will be possible to simply copy the original author's presentation of his results and to combine these with a summary of the experimental conditions. In many other cases, the original figures will not be adequate for purposes of the ICR study and changes will be required. These might be simple changes in scaling to allow comparisons of results across different studies. Taking a simple example, in some studies in which scene illumination level is an independent variable, the results are reported in terms of scene luminance and in others they are reported in terms of retinal illuminance. During the formatting process, these different units would be converted to a single unit that would allow the integration of results across the studies.

9.4 In some cases, data formatting will involve extensive manipulation of the experimental results. This might involve reinterpreting the test data in terms of different parameters of more use to the aircrew training device designer than the parameters used by the original authors. In a few cases, reinterpretation may be required because the original authors missed some of the implications of their results. This occurred, for example, in a recent review of experimental data on viewing distance requirements for television displays. In one study, the original authors presented their test data on target detection in terms of the angular subtense of the television monitor, but these data were both more consistent and more useful to the review when they were recomputed and summarized in terms of resolution elements across the target at detection.

APPENDIX B

DATA BASE AND USERS GUIDE DEVELOPMENT PLAN

1.0 Approach

At the simplest level, data base development consists of taking the information available in each of many topic areas, analyzing this information to determine the implications for ATD and human factors engineering, and then presenting these implications and the supporting information in the ICR data base. Carrying out this activity will require numerous interactive steps, as can be seen in the summary of the planned data base development illustrated in Figure B-1. The resulting products are summarized in Table B-1.

TABLE B-1. Data Base and User's Guide Development Products

PRODUCT	CONTENT
ICR USER'S GUIDE	PURPOSE OF USER'S GUIDE AND DATA BASE
1. ATD-ORIENTED	ENTRY TECHNIQUES (USER ORIENTED)
	TABLES OF CONTENTS
	(SUMMARY LEVEL & DETAILED)
2. HUMAN FACTORS	INDEX
ENGINEERING ORIENTED	POTENTIAL CUE CONFLICTS
	POTENTIAL CUES FOR PARTICULAR TASKS
	HARDWARE FEATURE-RELATED ANALYSIS AND
	CHECKLISTS
	MISSION-RELATED ANALYSES
	DESIGN EXAMPLES ILLUSTRATING DATA BASE USE
	TUTORIALS AND BACKGROUND ON TECHNICAL AREAS
	GLOSSARY, DEFINITIONS, ABBREVIATIONS,
	ACRONYMS AND UNITS
	GUIDE TO PSYCHOPHYSICAL METHODOLOGY AND
	STATISTICS
ICR DATA BASE	RECOMMENDATIONS, SUGGESTIONS FOR DESIGN
	ANALYSES AND DISCUSSIONS
	EXTRACTED, FORMATTED, AND INTEGRATED DATA
	EVALUATION OF DATA ADEQUACY
	IMPLICATIONS OF INDIVIDUAL DIFFERENCES
	CROSS REFERENCES TO OTHER TOPICS
SUPPORTING DATA:	LITERATURE SUMMARIES AND EVALUATIONS*

*NOTE - UNLIKE THE USER'S GUIDE AND DATA BASE, THE LITERATURE SUMMARIES AND REVIEWS WILL NOT BE DELIVERED IN A FORM SUITABLE FOR GENERAL DISTRIBUTION.

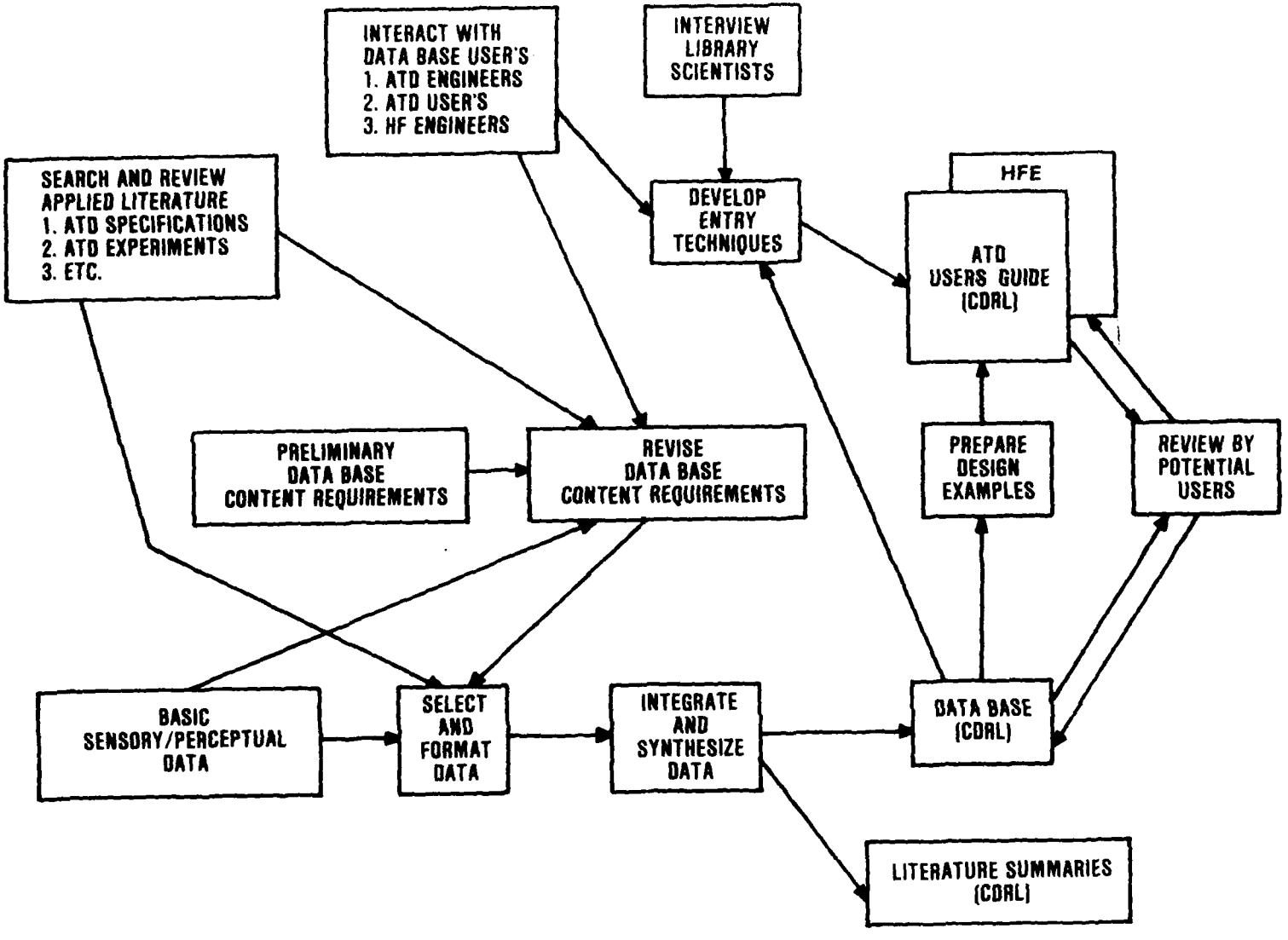


Figure B-1 Data Base and Users Guide Development Flow

2.0 Data Selection and Integration

The heart of the data base development process is the integration of the data covering a particular topic area into the form in which it will appear in the data base. This is a process that involves, for each topic area, a series of steps. In many cases, these steps are performed iteratively.

2.1 A promising set of data from an experiment or group of experiments that appears to be relevant to the topic area is identified.

2.2 The report of each experiment is reviewed to determine that the experiment was properly performed and the results are valid. Factors considered include the test hardware and procedure, the test subjects and their training, the experimental design, and the data analysis.

2.3 The results of other experiments are reviewed to determine if they confirm or contradict the data.

2.4 The data are integrated with data from other comparable experiments if these are available and if the additional data are needed in the data base.

2.5 The data are summarized in an easy-to-interpret graphic format.

2.6 The data and the experiment(s) that led to these data are described. This description covers what was done in the experiment and the implications and limitations of the resulting data.

2.7 Design recommendations summarizing the implications of the data for hardware and system design are prepared.

The data integration activity will benefit from numerous techniques and sources. For example, when several experiments are available that indicate the contribution of a particular variable, these can be considered simultaneously by computing the proportion of the variance in each experiment that was accounted for by the variable. Review articles and texts summarizing a particular topic area will provide guidance in understanding the area and in

integrating the available data. Perceptual principles and models, either previously published or provided within the government-furnished sensory/perceptual data, will provide a tentative framework within which the available data can be integrated and summarized. It will be essential to assess the usefulness of this integration by comparison with the data base content requirements. For example, a description of the principles underlying the perception of motion in depth may be useful as a means of integrating a disparate set of test data and may be useful to the scientific community as a source of hypotheses to be tested experimentally. However, it belongs in the ICR data base only if it contributes to an understanding of how best to achieve ATD or human engineering design goals. As the sections of the data base are completed, they will be reviewed by potential users who will attempt to use them to solve hypothetical design problems. The results of these reviews will then be used to revise the data base.

3.0 Entry Technique Development

Because the information in the data base will be used extensively only if it can be easily located, major emphasis will be placed on the development of access methods. With the exception of cross references from one technical area to the other within the data base, these access methods will be contained in the Users Guide.

The access methods provided will be organized around the needs and interests of the potential users. For example, the emphasis in the index will be on the terminology of engineering rather than perceptual psychology. This goal will be achieved by extensive interaction with potential users before and during the preparation of the access methods, and later by revising these methods based on reviews by potential users.

4.0 Data Base Organization

The ICR data base will be structured to make it easily accessible to the primary users, ATD designers and human factors engineers. To achieve this goal, the technical material in the data base will be organized into sections and subsections that contain the fundamental sensory/perceptual information

used in the specification of design requirements. Each of the design problem areas requires information from more than one section of the data base. Conversely, each section of the data base will apply to several design problem areas. The Users Guide will direct the user to the sections applicable to his design problem.

Within these design-oriented topics, the information of importance to a particular user will vary according to the intended function of the hardware or system being designed. For example, an ATD intended for training an individual to detect, identify and assess, and respond to the intended action of another aircraft in a tactical combat scenario must meet more stringent image resolution criteria than one intended for training an individual to land an aircraft. These types of task-related differences in ATD design requirements will be treated in the ICR Users Guide, where the available knowledge on the cues that may be involved in performing various aircrew tasks will be discussed. This discussion will make the ICR user aware of the cues that should be provided when training a particular type of performance and will direct him to the sections in the ICR data base where they are discussed in more detail. Within the data base, the impact on design requirements of these variations in cue requirements for different tasks will be discussed and the appropriate data base material (recommendations, implications for design, supporting research data, etc.) will be presented for each major task application.

Within particular topic areas, perceptual principles and models will serve several functions. In some cases, they will provide a basis for design recommendations and approaches. For example, control system models of the human operator provide insight into permissible simulator transport delays. In other cases, perceptual principles and models will provide the framework around which the available research data on a particular topic can be organized. As an example, this approach will be useful in treating topics such as spatial orientation, where many features of the operator's environment contribute nonlinearly to the perceived orientation.

5.0 Required Data Base Content

The goal of the ICR program is to provide perceptual information to improve equipment specification and design. Therefore, the specific topics to be incorporated into the ICR data base will be selected to represent the user's needs. This list will undergo extensive evolution during the data base development, utilizing inputs from analyses of both equipment designers and users. Principles and models in the areas of sensation and perception will help interpret the needs of the users and organize the data in each of these areas.

The following criteria will be used in modifying the data base content requirements list and to help in establishing which topics have the highest priority for consideration during the ICR program. In order of preference, the greatest emphasis will be placed on the following:

5.1 Perceptual principles and data that are directly applicable to widely recognized design problems or to simulation techniques as applied to design features.

5.2 Perceptual principles and data of general value to equipment design.

5.3 Perceptual principles and data related to the basic processes involved in user activities.

5.4 All other types of data or information deemed useful or applicable to equipment design.

Within each of these categories, the available research data will be utilized based on the technical quality of the work and the extent to which the experimental design and subject population allows generalization to equipment design requirements.

The methods of presenting information in the data base will be designed to serve users with differing interests and backgrounds. Whenever feasible, the

presentation of each topic area will start with recommendations or implications for design. These will be supported by summaries of data from relevant research literature, formatted for easy access by the user. The analysis by which the design recommendations were derived from the research data will be included. In this way, the user who is severely time limited can take advantage of the recommendation and implications-for-design statements developed during preparation of the data base, while those users who have a need to do so can trace to the supporting data.

The specific methods of presenting material in the data base will be the following:

Recommendations and Implications for Design - These will represent the best summary available of a technical topic area as it applies directly to the specification or design of a particular ATD feature intended to perform some particular training task. Care will be taken to make these recommendations and implications-for-design statements clear, unambiguous and operationally oriented so they will lead directly to useful procurement specifications.

Analysis and Discussion - This material will expand on the recommendations and implications-for-design statements and show how they result from the research data summarized in the data base.

Research Data - The research data relevant to the technical topic area will be summarized in a form that facilitates comparisons between different research studies and an assessment of how much empirical support is available for the design recommendation of their validity and reliability and a summary of the test conditions sufficient to allow the data base user to assess whether the results apply to a particular ATD situation. Bibliographic citations will be included for the benefit of those users who wish to consult the original sources.

Tutorials - When necessary to ensure the data base user will understand the implications of the data and analysis in a particular topic area, background tutorial material will be provided. This material will be

presented at a summary level and will include references to publications where a more complete treatment can be found.

Frequent use will be made in the data base of cross references to relevant material in other sections. These will serve the same function as the entry techniques provided in the Users Guide, in that they will help make the user aware of the several topic areas that should be considered to solve a particular design problem.

6.0 Users Guide

The primary purpose of the ICR Users Guide is to provide means for easily and rapidly accessing and applying the material in the ICR data base. To achieve this goal, several entry techniques will be provided in the guide so that users with different interests, backgrounds, and levels of experience with the data base can determine what information within the data base is potentially relevant and can quickly and easily locate this information.

Among the entry techniques that will be incorporated into the User's Guide are the following:

Table of Contents - Two tables of contents will be included to provide access to information about a particular topic. One will be at a summary level and is intended for the individual desiring to quickly determine the overall scope and organization of the data base. The other will list essentially every subsection heading within the data base and will provide a means for locating material on specific topics. The summary table of contents will not exceed two pages while the detailed version will be six to perhaps ten pages long.

Index - An index will be included to provide access to information about a particular subject. To make the index more useful, it will contain both key words and phrases used in the data base text and terms descriptive of the content but not actually used there.

Design Features Analysis - This analysis will provide access to the data base in terms of specific hardware or software features. Examples of design features include display field of view, CRT raster line visibility, and spatial distribution of computer generated texture elements. Within each feature, a reference to a location in the data base will include a brief statement of why the material in that section is relevant.

Design Features Checklist - This list will serve to review for the user the various topics that should be considered in the specification or design of an ATD intended for a particular purpose. Included with each topic area in the checklist will be an indication of the data base section or sections where it is covered. It is anticipated the checklist items will be phrased as questions. For example, the checklist for an ATD intended to be used in training aircrew personnel to recognize and respond to other aircraft in a tactical air combat situation might include these entries:

- Are the visual display resolution and contrast adequate?

- Can the displayed other aircraft be made perceptually equivalent to the operational situation?

- Is the visual display field of view adequate?

- Will the visual display collimation impose realistic requirements on the visual accommodation of aircrew personnel during search?

Mission-Related Design Feature Analyses - This analysis will provide access to the data base by the design features required to simulate a particular type of mission. For example, a simulator designed to train pilots in landings and takeoffs will probably not be adequate to train for nap-of-the-earth flight. A simulator designed to train air-to-air combat will require higher resolution than one designed to train for nap-of-the-earth flight but would not require as much scene content.

Potential Cue Conflicts - This section will describe the cue conflicts that may result from a particular hardware/software implementation of an ATD and indicate where these are treated in the data base.

Potential Cues for Particular Tasks - Each aircrew task has a unique set of cues that must be considered during ATD specification and design if perceptual fidelity is to be achieved in the training situation. Although the specific cues involved in each task are not fully established, a considerable body of literature exists that provides useful guidance. This literature will be briefly summarized in the Users Guide to aid the ATD specifier/designer in deciding which cues to incorporate.

In addition to these entry techniques, the Users Guide will incorporate other material to aid individuals involved in ATD specification or design. These include:

Role of the ICR Users Guide and Data Base - This section will summarize the content, organization, and structure of the Users Guide and data base and will describe how these can be accessed and used to improve ATD specification and design.

Guide to Psychophysical and Statistical Methodology - This section is intended for individuals involved in testing or otherwise evaluating ATDs. It will summarize some of the approaches to such evaluations, describe some of the numerous potential pitfalls, and suggest potential sources of experienced guidance and assistance.

Design Examples - To make the accessing and application of the material in the data base more apparent, this section will contain examples of typical ATD design problems and illustrate how they would be improved through use of material from specific sections of the data base.

Tutorials - This section will contain background technical material to assist data base users in understanding and interpreting the data presented in the data base.

APPENDIX C

STRUCTURED REVIEW FORM

1.0 Study Assumptions

The ICRS approach is based on the four assumptions listed below. Please comment, as appropriate, on the potential validity and the importance to study success for each of these assumptions.

1.1 Information germane to the questions of cue utilization and the influence of cues on control inputs exists in the basic perceptual literature.

1.2 Perceptual information germane to the questions of cue utilization and the influence of cues on control inputs will be useful for defining the engineering requirements for training simulators.

1.3 The source and content of cues are a function of the aircraft system, mission and individual variables relating to the pilot and his previous training. The scope of the present study does not permit a thorough investigation of all possible combinations and permutations of these parameters, nor are there good reasons to believe that this would be a reasonable approach to pursue. Instead, for the present investigation, we are assuming that (a) there are some aspects of cues that are constant across each of these parameters and that (b) detailed information relating to these constants can be useful for the design and evaluation for retrofit design of ATDs.

1.4 ATDs designed using ICR data will be more effective training devices.

2.0 Literature Search and Review Plan

2.1 General Approach

(a) Are the planned activities feasible?

(b) What is the likelihood for success?

(c) Where are the potential problem areas?

(d) What can be done to improve the effort?

2.2 Literature Sources

Please indicate any suggestions for additions to the planned list of sources.

2.3 Screening and Prioritization Criteria

Several levels of screening are planned to select the most useful and relevant material. Do you have suggestions for modifications or additions to the criteria planned for this process?

2.4 Evaluation Criteria

Evaluation forms are planned for rating the most relevant literature. Do you have suggestions for modifications or additions to the criteria listed?

2.5 Summary Form

Reviewers will be expected to summarize individual articles using a standardized format. Do you have suggestions for modifications or additions to the planned Report Summary Form?

3.0 Data Base Development Plan

The development of the Data Base and User's Guide is certainly the most critical step in the ICRS. The following items are considered to be especially important for effective performance in this effort. Your comments concerning the feasibility of the current plans and suggestions for improvement are requested.

3.1 Preliminary Topic List

3.2 Approach to Identification of Topics

(a) ATD Design Parameter Categories

(b) Training Cue Categories

(c) Perceptual Categories

3.3 Data Integration Process

(a) Entry Techniques

(b) Design Recommendations

(c) Tutorial Material and Analyses

(d) Extracted and Formatted Data

3.4 Organization of Users Guide/Data Base

4.0 Demonstration Study Plan

4.1 Specific Problem Areas

The general area of spatial/temporal mismatch has been selected for the demonstration study topic. This total area, however, is too broad for the planned level of effort. Specific items will be considered based on the availability of useful information and the significance of the expected impact on simulator design. Suggestions for or against specific items to be considered will be helpful.

4.2 Simulated Design Exercises

This step is intended to enhance the contribution of the user population to the development of the organization and format of the User's Guide and Data

Base. Do you consider this approach to be a reasonable one? Can you suggest alternate or additional efforts to maximize user contributions to the study effort?

4.3 Impact on ATD Specifications and Evaluation

The preliminary Users Guide and Data Base developed in the demonstration study is expected to provide the basis for demonstrating the validity of the study assumptions and the feasibility of the planned approach. The intent is to use a range of expertise to identify examples of significant contributions of these materials to simulator design. Can you suggest a better approach for demonstrating the potential benefits of the planned study?

5.0 Overall Assessment

In addition to the individual items noted above, your assessment of the overall study approach is desired. Summary statements are needed in the following areas:

(a) Feasibility of the overall study approach.

(b) Likelihood of successfully achieving the study objectives.

(c) Identification of potential problem areas.

(d) Suggestions for improving the likelihood of success.

Comments on the overall structure and scheduling of the program should be included as appropriate.

APPENDIX D

USERS EVALUATION FORM

The ICR Study will integrate the data on human perception applicable to the design of Aircrew Training Devices (ATDs) in a manner that will make these data helpful to engineers charged with the specification, design or evaluation of such equipment. The output from ICR will be a set of documents containing the integrated data and providing a means for easy access.

A small sample of the ICR documentation has been prepared and is currently undergoing review. By involving the ATD engineer in this review, the final product will benefit from the opinion and experience of the ultimate user. Because of your position and expertise, you have been requested to participate in this review.

As you review this material, keep in mind that what you see in the document before you is but one small portion of the final total output of this study. As a result, it covers only a small sample, perhaps five percent at most, of the large body of relevant and potentially useful data.

Our primary concern is to achieve a document which will have maximum utility to the engineer involved with ATDs. Thus, we will be asking you to consider the following issues:

1. ACCESS - Are the data arangement and data access methods (index, table of contents, etc.) such that you can access the data efficiently and speedily?

2. PRESENTATION - Are the format and manner of presentation in the sample such that they allow easy use of the relevant data?

3. USEFULNESS - Is the type of perceptual data represented by this sample of value to the ATD design/development process?

In the following pages we will ask specific questions relating to these points. Please feel free to comment on any aspects of the material, whether we have asked about them or not. Remember also that ultimately the engineering community will be the user of this material and that it should therefore reflect the needs of that community.

In order to allow you to place our ICR review questions in better context, we have included here a series of hypothetical "design questions" which might be asked of an ATD engineer. Please use these design questions to help judge the ease of access, the format and presentation of the data, and the value of the data in solving such questions.

Your assistance in this review is greatly appreciated.

Before proceeding further with your evaluation, please refer to the following portions of the sample ICR documentation. These will help set the stage for the evaluation comments and questions.

Foreword
Contents (both short and long versions)
Section 1.0 Introduction to ICR
Section 2.0 How to Access ICR

DESIGN QUESTIONS

Because you will be better able to assess the ICR documentation after using it, we have included several hypothetical design questions below. We suggest you use a few of these or similiar design questions to try out the entry methods provided in the Users Guide and then to assess the presentation of the data in the Data Base. You are welcome to substitute your own design questions, but please remember that only part of the Users Guide and two sections of the Data Base are completed.

When you finish on this page, the following pages provide space for you to record your assessment of the accessibility, presentation and usefulness of the data.

(1) A simulator is being designed to train nap-of-the-earth flight. Interaction with other aircraft will not be trained in this device. A visual display will be placed in the windscreen area immediately in front of the aircraft, filling about 20 degrees on either side of the centerline. Assume that because of design constraints only a small portion of the remainder of the pilot's field of view can be provided with a visual display. What areas have highest priority for this display?

(2) What, if any, are the detrimental effects of allowing the raster lines to be visible in an ATD visual display intended for training nap-of-the-earth flight?

(3) Assume that a new algorithm for generating texture in a CIG scene has been developed. It is appealing because it provides a computationally efficient way of providing more edges in the scene. However, the texture is not perspectively correct because it is generated in the screen plane, rather than in image space. This means that when the texture is placed on a surface that slopes away from the observer, the texture elements do not get smaller with distance. Is this texture suitable for a visual display to be used to train low-level flight?

(4) The texture in (3) is composed of regularly spaced elements, all the same size. Is this better or worse than another texture composed of irregularly sized elements with an irregular spacing?

(5) How many image details (edges, faces, etc.) should be provided in a CIG visual scene so that it will be most effective in giving a pilot a sensation of actual flight in a-nap-of-the-earth trainer?

(6) In ATDs, a display portraying external visual scenes is generally designed so that the image is at a distance near optical infinity, say beyond 20 to 40 feet. What data support the additional expense entailed in placing the displayed image at this distance, rather than much closer? For example, it would be much less expensive to dispense with the typical collimating mirror and beamsplitter and simply mount the CRT display just outside the aircraft windows.

Now that you have looked at the various portions of the sample ICR documentation, please give us your impressions. In addition to the specific questions below, we welcome any additional comments or suggestions you may have. If you wish, you may write comments in the ICR documentation. (We will supply you with a replacement copy if you want one.)

Because your time is limited, the questions below are phrased to cover the whole documentation package. However, multiple responses, each referenced to specific portions of the documentation, are especially helpful.

A. ACCESS

A1. How easy was it to locate material relevant to a particular topic?

A2. Which methods of access did you use?

A3. Which method(s) of access are most effective?

B. PRESENTATION OF DATA

B1. How easy was the presentation format to follow?

B2. How easy was it to interpret the data and recommendations presented?

B3. Did the descriptions of experiments contain sufficient detail to allow you to judge the applicability of the experimental data to your specific design questions?

B4. Did the presentation allow you to see the extent to which a recommendation was supported by research data?

B5. Are there additional aspects of the presentation on which you wish to comment?

C. USEFULNESS

C1. How useful a resource will the ICR documentation be in its final form? (Base your response on the small sample you have seen, plus the indications of eventual content provided by the tables of contents and other portions of the Users Guide.)

____Extremely useful
____Very useful
____Moderately useful
____Slightly useful
____Not useful

C2. What additional ATD design topics or types of perception data particularly deserve attention in the ICR study? (The tables of contents and other portions of the Users Guide provide an indication of the content currently planned.)


DATE
ILME